REFERENCE 10

Tetra Tech, August 11, 1995,
Willamette River Basin Water Quality Study,
A Summary of Recent Scientific Reports on the Willamette River.

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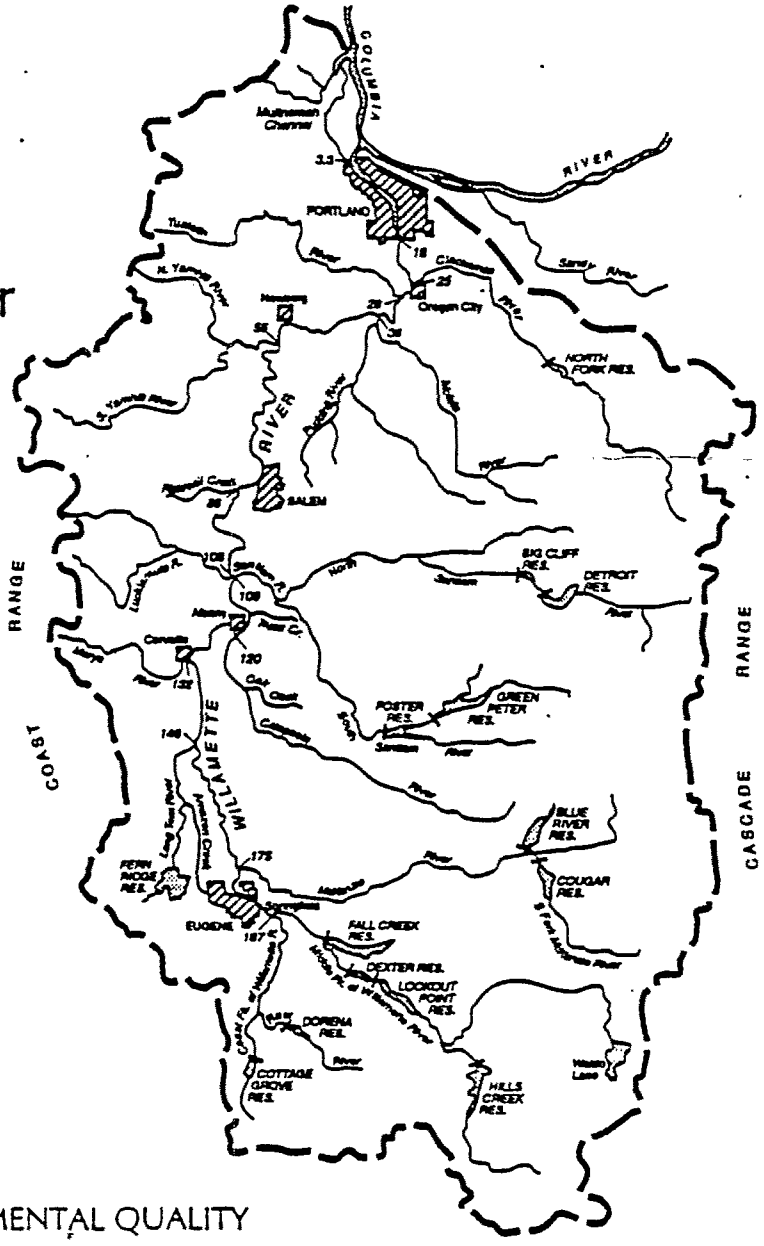
WILLAMETTE RIVER BASIN WATER QUALITY STUDY

A Summary of Recent Scientific Reports on the Willamette River



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Prepared For:

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY
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PORTLAND, OREGON 97204

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WILLAMETTE RIVER BASIN WATER QUALITY STUDY

A Summary of Recent Scientific Reports on the Willamette River

AUGUST 11, 1995

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A SUMMARY OF RECENT SCIENTIFIC REPORTS ON THE WILLAMETTE RIVER

OVERVIEW

In 1990, the Oregon Department of Environmental Quality and other agencies began an extensive study of the Willamette River Basin. The purpose of this study, called the Willamette River Basin Water Quality Study (WRBWQS) was to give decisionmakers who deal with the river scientific tools to help them predict what effects their decisions will have. Over 40 reports have been published in the course of this study to date. This report is a brief summary and synthesis of the findings of this study. It is organized into three sections:

- **Chapter 1** introduces the river and the study.
- **Chapter 2** summarizes the findings of the study.
- **Chapter 3** draws the findings together to state what we know about the basic health of the river.

If you're interested in a particular aspect of the river, we strongly encourage you to read the reports on that topic; you'll find final reports for each topic listed in the Appendix. This is a brief, condensed summary of a large set of published findings. For a more extensive technical summary of the WRBWQS, read *Willamette River Basin Water Quality Study: Summary and Synthesis of Findings* (Tetra Tech 1995), from which this summary is drawn.

CHAPTER 1: INTRODUCTION

A BRIEF HISTORY

When the first European American settlers arrived in the 1830s, the Willamette looked very different than it does today. Flow varied dramatically, with frequent floods during rain and snowmelt. In the valley, the channel was braided and shallow, spreading out into marshes miles wide at points. Humans have cleared forests, drained marshes, and made the channel narrower, deeper, and straighter. Snags were cleared, streamside trees removed, dams built, and banks stabilized. The Willamette was transformed from a wild river into a useful waterway for human purposes. It is unlikely that this process will be reversed and the Willamette made wild again.

Concern about the water quality and general health of the Willamette goes back at least to the turn of the century. The Willamette Valley was the part of the Oregon Territory first settled by European Americans, and the river served the settlers as a major transportation artery, water source, and sewer. These roles, especially the dumping of waste, resulted in a serious degradation of water quality. By the 1920s, the river was badly polluted with raw sewage and industrial wastes from paper mills, sugar beet processors, and meat packers. Dissolved oxygen fell low enough to prevent the passage of game fish, and bacteria levels made the water unsafe for any human use. Cleanup efforts began in the 1940s, but it wasn't until secondary wastewater treatment was instituted in the 1970s that the river again became a place where people could swim and salmon could spawn. It was a striking success story and a highlight of national environmental protection efforts. But recent studies have found other problems like trace metals, synthetic organic compounds, suspended sediments, soil nutrients, and altered habitats at a number of places in the Willamette and its tributaries. Despite the great improvements of the last 50 years, continued concern about the health of the Willamette is justified.

THE WILLAMETTE RIVER AND BASIN

The Willamette is the largest river in Oregon (not counting the Columbia) and in many respects the most important. It drains a basin in northwestern Oregon between the Coast Range and the Cascades that covers 11,500 square miles, about 12% of Oregon's land area, but has a population approaching 2 million, well over half the state's population, and the proportion is growing. Population growth is especially rapid in the basin's urban areas centered in Portland, Salem, and Eugene—the state's three largest cities. Fertile soil and abundant rainfall have made the valley the most important agricultural region in the state, and along with urban population growth has come industry of all kinds.

The river flows 295 miles north from its headwaters in southwestern Oregon to the Columbia River. Based on average water volume (23,000 cfs at Salem), it is the tenth largest river in the U.S. This is the result of annual precipitation that ranges from 40 inches in the valley up to as high as 90 in the mountains. The river system includes the main stem, which is 187 miles long, and 13 major tributaries.

For the purposes of this study, the Willamette has been divided into four reaches, or regions:

- **The Tidal Reach**—from the Columbia to Willamette Falls; 26.5 miles. Pacific tides sometimes cause Columbia River water (not Pacific water) to flow up into this reach.

- **The Newberg Pool**—from the Falls to a short ways above Newberg; 35.5 miles. This is the area where water gathers behind Willamette Falls.

- **The Salem Reach**—from the top of the Newberg Pool to Corvallis; 71 miles. The river is shallower, faster, and harder-bottomed here than in the lower reaches.

- **The Headwaters**—above Corvallis; 56 miles. Also fast, shallow, and hard-bottomed.

Figure 1 is a map of the basin showing the four reaches.

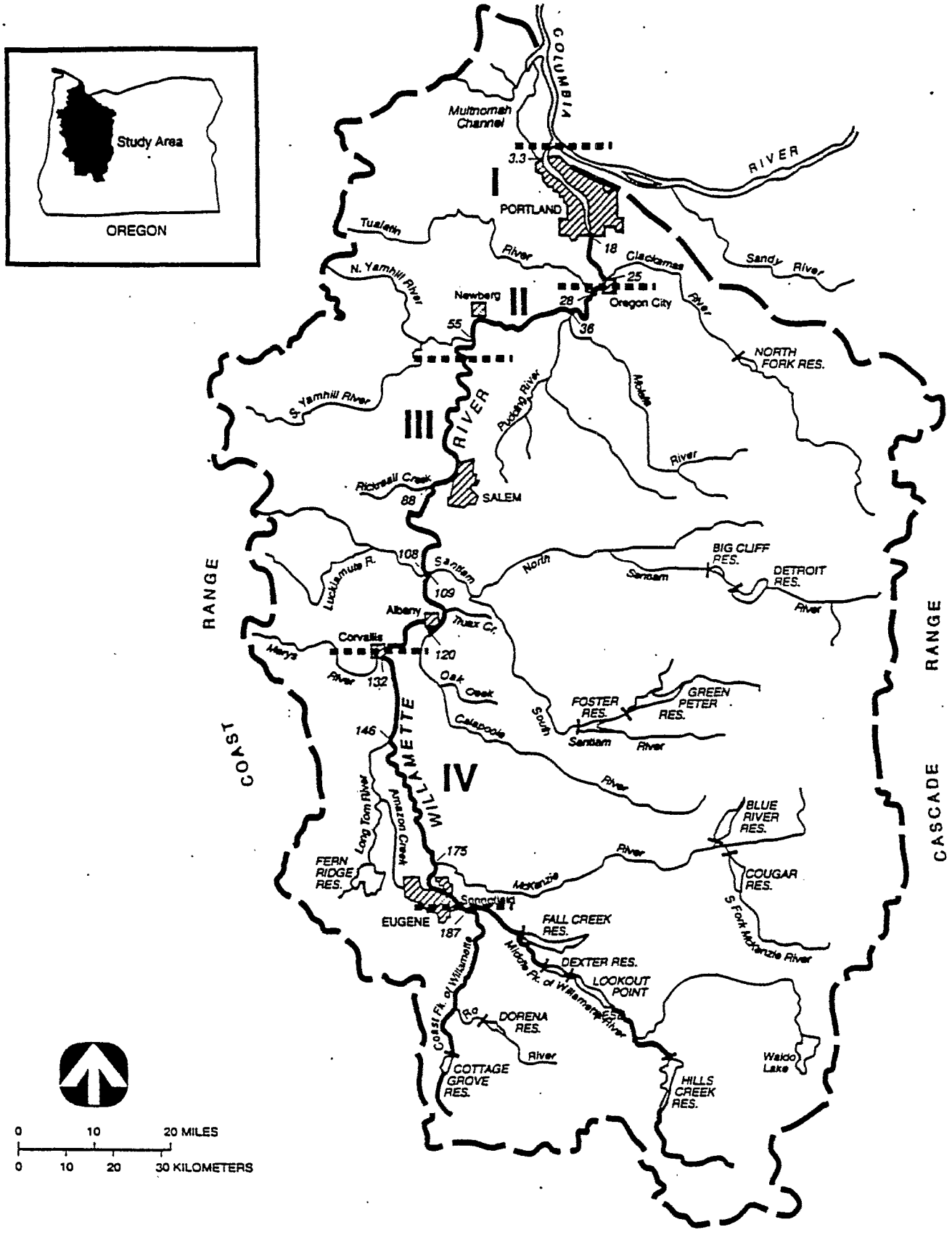

Figure 1. Willamette River Basin Water Quality Study Area and the Four River Regions.

OBJECTIVES OF THE STUDY

The Department of Environmental Quality (DEQ) has identified the protection of the Willamette River as one of the most important resource management goals of the state. The purpose of this study is to support this goal by giving DEQ and others concerned with the health of the river better tools for planning and decisionmaking, and allow them to take a proactive approach to river management rather than just reacting to identified water quality problems. It was authorized by the Oregon Joint Legislative Emergency Board in April 1990. The study has two related objectives:

- Develop tools to help water managers assess current water quality and predict how future changes might impact that water quality

- Collect data necessary to develop, test, and refine these tools

The tools being developed are predictive water quality models, sophisticated computer simulations that use what is currently known about the river and how it has changed in the past to predict how it will change under future pressures. This lets river managers have a good idea of what will happen to water quality if, for instance, river flows are changed or new industries are granted permits to discharge wastewater to the river. It also lets them predict the effects of changes in population and land use, and plan for crises before they arise.

CHAPTER 2: FINDINGS

The purpose of this study was not to assess the health of the Willamette River; it was to develop tools to allow river managers to assess and predict changes in water quality. However, a good deal of information that relates to the health of the river was collected in the process of developing and refining these tools, and it is possible to organize this into a preliminary assessment of the health of the river.

Four different areas or aspects of the river were studied:

- Water quality
- The health of bottom dwelling organisms
- The health of fish
- The quality of natural habitats in the river

WATER QUALITY: POLLUTANTS AND BALANCES

In looking at how clean or polluted water is, we consider pollutants from two general sources. *Point source pollutants* are the kind that can (and usually do) come out of a pipe. There's a specific, identifiable source, like a factory or a sewage treatment plant. *Nonpoint source pollutants* are not so trackable. They come out of the soil as water flows over it, or settle out of the air, or seep out of many small sources, or get washed off roadways when it rains.

Nonpoint source pollutants can be substances that occur naturally at that site, such as soil nutrients like nitrogen or phosphorus that are necessary for plant growth, but which act as pollutants when too much of them gets in the water. Or they can be toxic substances that have spilled on the soil or leaked into the atmosphere, and then entered the water by leaching or settling. Point sources of pollutants in the Willamette, like sewage treatment plants and pulp and paper mills, are closely monitored and regulated

by the Department of Environmental Quality, and contribute significantly less pollution to the river than they did in the past. Nonpoint sources, like runoff from agricultural land and roadways are much more difficult to regulate because of the difficulty of determining accurately the amounts and sources of pollutants entering the river.

As the amount of pollutants entering the river from point sources has been reduced, the relative contribution of nonpoint pollutants has increased. However, the relative importance of these two pollutant sources can vary seasonally. Most of the nonpoint pollution occurs in the winter and spring, when heavy rains wash pollutants into the river. Most point sources, on the other hand, discharge year round, and during summer low water periods, they can have a greater impact on the river than point sources.

A common nonpoint source pollutant in the Willamette River is soil particles eroded from river banks or otherwise washed into the river. In undisturbed conditions, most rivers and streams have few suspended particles because forests and grasslands hold the soil in place. Soil particles become a problem when the soil or vegetation is disturbed, by logging, agriculture, building, road construction, and so forth. In general, suspended particle loads in the Willamette River Basin are highest in areas where the main land use is agriculture. Table 1 ranks the tributary basins of the Willamette according to the amount of suspended particles they were found to contain.

In urbanized areas like the Tidal Reach, nonpoint sources are more varied, and pollutants more numerous. Some of the most polluted water tested was runoff from Interstate 5 near Portland.

Another kind of water pollution has to do with chemical balances. Clean water has a variety of physical and chemical factors—dissolved oxygen, hardness, pH, temperature—that act as pollutants when they're out of balance: too far one way or the other. Historically, Willamette River water was often very low in dissolved oxygen, a common effect of sewage and other organic wastes. Levels were low enough to create a barrier that salmon could not pass through. Dissolved oxygen levels are generally good now that wastes receive secondary treatment, but river managers still watch this factor closely, to make sure water quality is maintained.

TABLE 1. RANKING OF THE NONPOINT SOURCE POLLUTANT LOADS IN THE WILLAMETTE RIVER BASIN

Sub-Basin (Rivers)	Region	TSS	TP	NO_3
Severe Water Quality Problems				
Pudding	II	1	1	1
Columbia	I	2	2	5
Tualatin	II	3	3	4
Long Tom	IV	4	4	2
Coast Range (Yamhill, Luckiamute, Marys)	II, III, IV	5	5	3
Moderate Water Quality Problems				
Santiam	III	6	6	6
Clackamas	I	7	7	7
Mild Water Quality Problems				
Coast Fork (Willamette)	IV	8	8	8
Middle Fork (Willamette)	IV	9	9	9
McKenzie, lower	IV	10	10	10

THE HEALTH OF BOTTOM DWELLERS

Organisms that live in or on the bottoms of rivers—mostly insects, worms, and shellfish—can indicate a lot about the health of the river. Pollutants tend to accumulate in the sediments they live in, and unlike fish, bottom dwellers tend to have a very limited range. Their health thus reflects more specifically the health of that specific part of the river. Considerable scientific research has been devoted to evaluating these organisms and the changes that pollutants cause among them. Research done in this area for the WRBWQS has focused on developing tools and procedures: which organisms to measure and how to do it. The information generated by this research has provided a valuable baseline for comparing future findings with. It has also been used to compare the relative health of one part of the river with another. Generally, bottom dwellers were found to be healthier in the upper reaches of the river.

FISH HEALTH

Two complementary approaches were taken in assessing fish health: community and individual assessment. For the community assessment, different areas of the river were studied to see what species predominated; certain species require very clean water to thrive, while others can adapt to considerable amounts of pollution. Also of interest is the proportion of native versus introduced species. Individual assessments involved capturing and examining individual fish to detect specific abnormalities that have been associated with poor water quality. One study focused on skeletal deformities, while another did full autopsies on fish, looking at a wide array of health indicators.

The fish community assessment showed some impairment in all areas of the river, but with impairment increasing as you moved from the headwaters downriver. Skeletal deformities were within the normal, unimpaired range in the two upriver reaches (above Newberg), but showed widespread impairment in the Newberg Pool and the upper part of the Tidal Reach. The fish autopsy study was limited by migrational factors: most of the fish captured had moved upstream to spawn and thus did not necessarily represent the river region they were captured in. More information is needed about the life cycles and migrational patterns of these fish to do such a study.

HABITAT QUALITY

The health or quality of a river is not dependent solely on water quality. It can also decline with such changes in habitat as dredging, channel straightening, removing snags and streamside trees, and filling wetlands. An important part of the WRBWQS was developing a scale to measure the value of a particular site on the river as habitat for fish and other aquatic life. This scale showed impairment in all areas when compared to an ideal habitat, and the same general decrease in quality from the headwaters to the mouth.

CHAPTER 3: THE HEALTH OF THE WILLAMETTE RIVER

The State of Oregon has the general responsibility to protect the quality of rivers and other bodies of water in the public interest. What this means is spelled out in detail in a section of the Oregon Administrative Rules that lists the "beneficial uses" of the Willamette River that are to be protected by state agencies, particularly the Department of Environmental Quality. In summary form, these uses are:

- Water supply (public, private, and industrial)
- Irrigation and livestock watering
- Anadromous (migratory) fish passage, spawning, and rearing
- Resident fish, aquatic life, and wildlife
- Hunting and fishing
- Boating and water contact recreation
- Esthetic quality
- Hydro power
- Commercial navigation and transportation

In an attempt to synthesize the information provided by the WRBWQS, a river health index was developed. This index addresses each of the major aspects of river health that has been studied and assigns each of the four river reaches a score for each aspect of health. These individual scores were then averaged to derive an overall score for each reach and one for the river as a whole. Table 2 shows the score that each river region received for each aspect of health measured.

Many of these characteristics of river health are subjective or difficult to measure unambiguously. In creating a health index scale for the Willamette, the focus was on measurable criteria, and especially on established standards or suggested guidelines. Where no standards or guidelines existed, for instance for habitat quality, measurement was combined with professional judgment. Each factor studied—water and sediment quality, bottom dwellers, fish, habitats, and nonpoint sources—was scored on a scale from 1-9

TABLE 2. INDEX OF WILLAMETTE RIVER HEALTH

River Region	Health Indicators										Average
	Water Quality Standards and Guidelines				Benthic Communities		Fish		Habitat	Nonpoint Sources	
	Dissolved Oxygen	Chlorophyll *a*	Toxics - Water	Toxics - Sediment	Soft-bottom	Riffle	Index of Biotic Integrity	Skeletal Deformity			
4	9	9	4.9	4.5	6.5	5.8	5.7	9	5.5	5.9	6.6
3	7	9	5.5	3.8	4.9	5	5.2	2.5	5	4.5	5.2
2	9	9	3	2.3	5	--	4.3	1	4.7	3	4.6
1	9	9	3.3	1.2	4.6	--	3.8	4.5	2.8	4.3	4.7
Indicator Average	8.5	9	4.2	3.0	5.3	5.4	4.7	4.3	4.5	4.4	
Overall Willamette River Health Index Score											5.3

RIVER HEALTH INDEX	Score
Scoring Criteria:	
Excellent Health; No Evidence of Impairment or Exceedance of Available Standards or Guidance Values	9
Good Health; Occasional Exceedances of Available Standards or Guidance Values	7
Marginal Health; Common Exceedances of Available Standards or Guidance Values	5
Poor Health; Consistent Exceedances of Available Standards or Guidance Values	3
Highly Impaired; Almost Always Exceeds Available Standards or Guidance Values	1

for each of the four river reaches. These were the scores then averaged to arrive at an overall score for the river. The scores were defined as follows:

River Health Index Score	Description
9	Excellent Health; No Evidence of Impairment or Exceedance of Available Standards or Guidance Values
7	Good Health; Occasional Exceedances of Available Standards or Guidance Values
5	Marginal Health; Common Exceedances of Available Standards or Guidance Values
3	Poor Health; Consistent Exceedances of Available Standards or Guidance Values
1	Highly Impaired; Almost Always Exceeds Available Standards or Guidance Values

The Tidal Reach (the Columbia to Willamette Falls) : **4.8**

This is the most urbanized and industrialized area of the river, with drainage mostly from the Portland area. Standards and guidelines for toxics in water and sediments were commonly exceeded. Overall fish health was poor, and the quality of habitat was also impaired in many areas. The overall score of 4.8 indicates a marginal-to-poor condition overall.

The Newberg Pool (Willamette Falls to Newberg) : **4.7**

Fish health, as measured by skeletal deformities, was worse in this reach than in any other, with as many as 50% of all fish captured showing deformities at some sites. Standards and guidelines for toxics in water and sediments were commonly exceeded, particularly below Newberg. Dissolved oxygen levels were lowest in this region, and nonpoint source pollution, probably related to agriculture, was most pronounced. With an overall score of 4.7 the health of the Newberg Pool was about as marginal as that of the Tidal Reach, for slightly different reasons.

The Salem Reach (Newberg to Corvallis) : **5.3**

This reach had some exceedances of toxics guidelines and standards, and some evidence of fish health problems, but less so than the lower reaches. Most problems were noted near Salem or Albany. The overall score of 5.3 indicates marginal health.

The Headwaters (above Corvallis) : **6.5**

There were a few exceedances of toxics standards in this region, and some evidence of fish health problems, but overall the river health here is good. The overall score of 6.5 is good but not excellent.

The River as a Whole

The Willamette River has been extensively managed and shaped to serve the needs of the human population. Historical severe pollution problems from sewage have been controlled, and the river is dramatically healthier than it was 30 years ago. However, concern for its health is still justified by the presence of pollutants in water and sediments and the alteration of habitats. The health status of the river declines as you move downstream, from good in the headwaters to marginal-to-poor in the lower regions. Overall, the river is marginally healthy.

APPENDIX A: WILLAMETTE RIVER BASIN WATER QUALITY STUDY REPORTS

PHASE I:

COMPONENT 1: SCOPE OF WORK

Tetra Tech. 1992. Willamette River Basin Water Quality Study: Scope of Work. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech Inc., Redmond, WA. 69 pp.

COMPONENT 2: TOXICS MODELING

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 2: Review and summary of toxic pollutants in the Willamette River and major tributaries. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 39 pp. + appendices.

Tetra Tech and Limno Tech. 1992. Willamette River Basin Water Quality Study. Water quality model selection recommendation. Submitted by Limno-Tech, Inc. to Tetra Tech. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 22 pp.

Tetra Tech and Limno-Tech. 1993. Willamette River Basin Water Quality Study. Component 2: Toxic chemical model application report. Submitted by Limno-Tech, Inc. to Tetra Tech. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 67 pp. + appendices.

Tetra Tech and Limno-Tech. 1993. Willamette River Basin Water Quality Study. Component 2: Toxic chemical monitoring recommendations. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 33 pp.

Tetra Tech and Limno Tech. 1993. Willamette River Basin Toxics Component Report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 24 pp.

COMPONENT 3: DISSOLVED OXYGEN MODELING

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 3: Data review and summary for dissolved oxygen modeling on the Willamette River. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 54 pp. + appendices.

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Willamette River dissolved oxygen modeling component report. Volumes 1 and 2. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 135 pp. + appendices.

COMPONENT 4: NUTRIENTS AND ALGAL GROWTH MODELING

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 4: Review and summary of nutrient and phytoplankton growth data for the Willamette River. Final Report. Prepared for the Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 68 pp. + appendices.

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Willamette River nutrient and phytoplankton growth modeling component report. Final Report. Prepared for the Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 131 pp. + appendices.

Gregory, S.V. 1993. Willamette River Basin Study. Water quality dynamics—periphyton algal dynamics. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. 88 pp.

COMPONENT 5: BACTERIA MODELING

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 5: Review and summary of bacterial conditions in the Willamette River and major tributaries. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA.

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Component 5: Bacteria monitoring recommendations. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 33 pp.

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Willamette River basin bacteria component report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 55 pp.

COMPONENT 6: BIOLOGICAL RESPONSES TO STRESSORS

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Willamette River basin biological responses to stressors component report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 37 pp. + appendices.

COMPONENT 7: POINT SOURCES

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 7: Point source discharges and waste loading to the Willamette River Basin during 1991. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 61 pp. + appendices.

COMPONENT 8: NONPOINT SOURCES

Tetra Tech and E&S Environmental Chemistry. 1992. Willamette River Basin Water Quality Study. Component 8: Literature review and summary of nonpoint source pollution in the Willamette River Basin. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 77 pp. + appendices.

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Tetra Tech and E&S Environmental Chemistry. 1993. Willamette River Basin Water Quality Study. Component 8: Nonpoint source pollution model application. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 147 pp. + appendices.

Tetra Tech and E&S Environmental Chemistry. 1993. Willamette River Basin Water Quality Study. Component 8: Nonpoint source pollution monitoring design. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 38 pp.

Tetra Tech and E&S Environmental Chemistry. 1993. Willamette River Basin Water Quality Study. Willamette River Basin nonpoint source component report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 34 pp.

COMPONENT 9: ECOLOGICAL SYSTEMS INVESTIGATIONS

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 9: Characterization of Willamette River main-stem ecoregions. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 27 pp.

Tetra Tech. 1993. Willamette River Basin Water Quality Study. Willamette River ecological systems investigation component report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 164 pp. + appendices.

COMPONENT 10: PROJECT SUMMARY REPORT

Tetra Tech. 1993. Willamette River Basin Water Quality Study: Summary Report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 167 pp. + appendices.

COMPONENT 11: FIELD SURVEY

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 11: Field sampling plan: Water quality model calibration and ecological assessment. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 69 pp. + appendices.

Tetra Tech. 1992. Willamette River Basin Water Quality Study. Component 11: Water quality survey data. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 56 pp. + appendices.

PHASE II:

Tetra Tech. 1994. Willamette River Basin Water Quality Study. Phase II: Biological Sampling Data Report. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech Inc., Redmond, WA. 47 pp. + appendices.

Tetra Tech. 1994. Willamette River Basin Water Quality Study. Phase II: Scope of Work. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech Inc., Redmond, WA. 79 pp.

NONPOINT SOURCE COMPONENT

Tetra Tech and E&S Environmental Chemistry. 1994. Willamette River Basin Water Quality Study. Phase II: Nonpoint Source Sampling and Analysis Plan. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 45 pp.

Tetra Tech and E&S Environmental Chemistry. 1994. Willamette River Basin Water Quality Study. Phase II: Land use characterization of the Pudding River sub-basin and selected watersheds. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech, Inc., Redmond, WA. 37 pp.

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ECOLOGICAL MONITORING COMPONENT

Tetra Tech. 1994. Willamette River Basin Water Quality Study. Phase II: Ecological monitoring component: Benthic metric selection and data evaluation. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech Inc., Redmond, WA. 70 pp. + appendices.

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INTEGRATION COMPONENT

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Tetra Tech. 1995. Findings of the Willamette River Basin Water Quality Study. Final Report. Prepared for Oregon Department of Environmental Quality, Portland, OR. Tetra Tech Inc., Redmond, WA.

STEADY-STATE MODEL REFINEMENT COMPONENT

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U.S. Geological Survey. 1995b. Ancillary Information and Data Tables for the Pesticide and Trace Element Study by the US Geological Survey as Task 1 of the Phase II Willamette River Basin Water Quality Study, 1994. Preliminary Draft. Prepared for Oregon Department of Environmental Quality, Portland, OR. U.S. Geological Survey, Water Resources Division, Portland, OR.